




CHEMISTRY I

for PRE-UNIVERSITY

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for Pre-University

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The Periodic Table of Elements

| 1 | | | | | | | | | | | | | | | | | 18 |
|-------------------------------|-------------------------------|---------------------------------|-------------------------------------|-------------------------------|----------------------------------|--------------------------------|--------------------------------|----------------------------------|------------------------------------|-----------------------------------|------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------------|-----------------------------|
| 1.0 H Hydrogen 1 | | | | | | | | | | | | | | | | | 4.0 He Helium 2 |
| 6.9 Li Lithium 3 | 9.0 Be Beryllium 4 | | | | | | | | | | | | | | | | |
| 23.0 Na Sodium 11 | 24.3 Mg Magnesium 12 | | | | | | | | | | | | | | | | |
| 39.1 K Potassium 19 | 40.1 Ca Calcium 20 | 45.0 Sc Scandium 21 | 47.9 Ti Titanium 22 | 50.9 V Vanadium 23 | 52.0 Cr Chromium 24 | 54.9 Mn Manganese 25 | 55.8 Fe Iron 26 | 58.9 Co Cobalt 27 | 58.7 Ni Nickel 28 | 63.5 Cu Copper 29 | 65.4 Zn Zinc 30 | 69.7 Ga Gallium 31 | 72.6 Ge Germanium 32 | 74.9 As Arsenic 33 | 79.0 Se Selenium 34 | 79.9 Br Bromine 35 | 83.8 Kr Krypton 36 |
| 85.5 Rb Rubidium 37 | 87.6 Sr Strontium 38 | 88.9 Y Yttrium 39 | 91.2 Zr Zirconium 40 | 92.9 Nb Niobium 41 | 95.9 Mo Molybdenum 42 | (98) Tc Technetium 43 | 101.1 Ru Ruthenium 44 | 102.9 Rh Rhodium 45 | 106.4 Pd Palladium 46 | 107.9 Ag Silver 47 | 112.4 Cd Cadmium 48 | 114.8 In Indium 49 | 118.7 Sn Tin 50 | 121.8 Sb Antimony 51 | 127.6 Te Tellurium 52 | 126.9 I Iodine 53 | 131.3 Xe Xenon 54 |
| 132.9 Cs Caesium 55 | 137.3 Ba Barium 56 | 138.9 La* Lanthanum 57 | 178.5 Hf Hafnium 72 | 180.9 Ta Tantalum 73 | 183.8 W Tungsten 74 | 186.2 Re Rhenium 75 | 190.2 Os Osmium 76 | 192.2 Ir Iridium 77 | 195.1 Pt Platinum 78 | 197.0 Au Gold 79 | 200.6 Hg Mercury 80 | 204.4 Tl Thallium 81 | 207.2 Pb Lead 82 | 209.0 Bi Bismuth 83 | (209) Po Polonium 84 | (210) At Astatine 85 | (222) Rn Radon 86 |
| (223) Fr Francium 87 | (226) Ra Radium 88 | (227) Ac** Actinium 89 | (261) Rf Rutherfordium 104 | (262) Db Dubnium 105 | (266) Sg Seaborgium 106 | (264) Bh Bohrium 107 | (277) Hs Hassium 108 | (268) Mt Meitnerium 109 | (271) Ds Darmstadtium 110 | (272) Rg Roentgenium 111 | | | | | | | |

| | |
|--|------------|
| | Metals |
| | Nonmetals |
| | Metalloids |

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide Series

** Actinide Series

| | | | | | | | | | | | | | |
|------------------------------|-----------------------------------|--------------------------------|---------------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------|----------------------------------|----------------------------------|-------------------------------|-----------------------------------|--------------------------------|----------------------------------|
| 140.1 Ce Cerium 58 | 140.9 Pr Praseodymium 59 | 144.2 Nd Neodymium 60 | (147) Pm Promethium 61 | 150.4 Sm Samarium 62 | 152.0 Eu Europium 63 | 157.2 Gd Gadolinium 64 | 158.9 Tb Terbium 65 | 162.5 Dy Dysprosium 66 | 164.9 Ho Holmium 67 | 167.3 Er Erbium 68 | 168.9 Tm Thulium 69 | 173.0 Yb Ytterbium 70 | 175.0 Lu Lutetium 71 |
| 232.0 Th Thorium 90 | (231) Pa Protactinium 91 | 238.0 U Uranium 92 | (273) Np Neptunium 93 | (242) Pu Plutonium 94 | (243) Am Americium 95 | (247) Cm Curium 96 | (245) Bk Berkelium 97 | (251) Cf Californium 98 | (254) Es Einsteinium 99 | (253) Fm Fermium 100 | (256) Md Mendelevium 101 | (254) No Nobelium 102 | (257) Lr Lawrencium 103 |

Contents

| | |
|---|-----------|
| Preface | xxi |
| 1 CHEMISTRY AND CHEMICAL NOMENCLATURE | 1 |
| 1.1 Introduction | 1 |
| 1.2 Matter, Elements and Compounds | 1 |
| 1.2.1 Symbols and Formulae | 3 |
| 1.3 Measurement in Scientific Study | 3 |
| 1.3.1 Mass, Weight and Density | 5 |
| 1.3.2 Temperature and heat | 5 |
| 1.3.3 Uncertainty in Measurement – Significant Figures | 6 |
| 1.3.4 Precision and Accuracy | 10 |
| 1.3.5 Dimensional Analysis | 12 |
| 1.4 Fundamental Particles of Atoms | 14 |
| 1.4.1 Subatomic Particles of an Atom | 14 |
| 1.4.2 Effect of Electric and Magnetic Fields on Subatomic Particles | 14 |
| 1.4.3 Atomic Number and Mass Number | 15 |
| 1.4.4 Isotopes | 15 |
| 1.5 Relative Mass of Atoms and Molecules | 16 |
| 1.5.1 Relative Isotopic Mass and Relative Atomic Mass | 16 |
| 1.5.2 Relative Molecular Mass and Relative Formula Mass | 16 |
| 1.5.3 Isotopic Abundance | 17 |
| 1.5.4 Determination of Relative Atomic Mass from Mass Spectrum | 18 |
| 1.5.5 Interpretation of Mass Spectra | 20 |
| Multiple Choice Questions | 24 |
| 2 STOICHIOMETRY | 29 |
| 2.1 Introduction | 29 |
| 2.2 Mole Concept and Mass | 29 |
| 2.2.1 Mole and Equation | 32 |
| 2.2.2 Mole Concept and Volume | 32 |
| 2.3 Units of Concentration of Solutions | 34 |
| 2.3.1 Molarity (M) | 35 |
| 2.3.2 Molality (m) | 37 |
| 2.3.3 Percentage by mass (% w/w) | 38 |
| 2.3.4 Percentage by volume (% v/v) | 39 |

| | | |
|----------|--|-----------|
| 2.3.5 | Part per million (ppm) and part per billion (ppb) | 39 |
| 2.3.6 | Mole fraction (X) | 40 |
| 2.3.7 | Converting units of concentration | 41 |
| 2.4 | Formulae and Equations | 43 |
| 2.4.1 | Naming Chemical Compound | 44 |
| 2.4.2 | Types of Chemical Formulae | 46 |
| 2.4.3 | Calculating Empirical Formulae and Molecular Formulae | 46 |
| 2.4.4 | Writing Chemical Formulae and Chemical Equations | 48 |
| 2.5 | Chemical Reactions in Solutions | 49 |
| 2.5.1 | Determination of Chemical Equation of a Precipitation Reaction | 49 |
| 2.5.2 | Calculating Molar Mass in Acid-Base Reactions | 50 |
| 2.5.3 | Calculating Amounts of Reactant and Product | 51 |
| 2.5.4 | Limiting Reactant | 51 |
| 2.5.5 | Percentage Yield | 53 |
| 2.5.6 | Atom Economy | 54 |
| 2.5.7 | Stoichiometry of Chemical Reactions in Solution | 55 |
| 2.6 | Redox Reaction | 57 |
| 2.6.1 | Some Definition of Redox Reactions | 57 |
| 2.6.2 | Oxidation Numbers | 58 |
| 2.6.3 | Types of Redox Reactions | 61 |
| 2.6.4 | Oxidising Agents and Reducing Agents | 62 |
| 2.6.5 | Ionic Equations for Redox Reactions | 63 |
| 2.6.6 | Balancing Redox Equations | 64 |
| | Multiple Choice Questions | 68 |
| 3 | THERMOCHEMISTRY | 73 |
| 3.1 | Introduction | 73 |
| 3.2 | Enthalpy | 73 |
| 3.3 | Specific Heat Capacity and Calorimetry | 75 |
| 3.4 | Standard Enthalpy Change of a Chemical Reaction | 78 |
| 3.4.1 | Standard Enthalpy Change of Formation | 78 |
| 3.4.2 | Standard Enthalpy Change of Combustion | 80 |
| 3.4.3 | Standard Enthalpy Change of Neutralisation | 82 |
| 3.4.4 | Standard Enthalpy Change of Atomisation | 83 |
| 3.4.5 | Standard Enthalpy Change of Hydration | 85 |

| | | |
|-------|---|-----|
| 3.4.6 | Standard Enthalpy Change of Solution | 85 |
| 3.5 | Hess's Law and Born–Haber Cycle | 86 |
| 3.5.1 | Applications of Hess' Law | 86 |
| 3.5.2 | Lattice Energy using Born–Haber Cycle | 89 |
| 3.6 | Entropy | 90 |
| 3.6.1 | Spontaneous Processes | 90 |
| 3.6.2 | Changes of Entropy | 91 |
| 3.6.3 | Changes in Entropy with Change of State | 93 |
| 3.7 | Free Energy, G | 94 |
| 3.7.1 | Relation Among ΔG , ΔH , and ΔS | 95 |
| | Multiple Choice Questions | 97 |
| | | |
| 4 | STRUCTURE OF ATOMS | 101 |
| 4.1 | Introduction | 101 |
| 4.2 | Electronic Energy Levels | 102 |
| 4.2.1 | Electromagnetic Radiation | 102 |
| 4.2.2 | Quantised Energy & Photons | 103 |
| 4.2.3 | Formation of the Hydrogen Spectrum | 103 |
| 4.2.4 | Bohr Model of the Hydrogen Atom | 105 |
| 4.2.5 | Ionisation Energy of the Hydrogen Atom | 107 |
| 4.3 | Atomic Orbitals | 108 |
| 4.3.1 | Quantum Numbers of an Atomic Orbital | 108 |
| 4.3.2 | The Shapes of Atomic Orbitals | 110 |
| 4.4 | Filling of the Orbitals in Many-Electron Atoms | 111 |
| 4.4.1 | Aufbau Principle | 111 |
| 4.4.2 | Pauli Exclusion Principle | 112 |
| 4.4.3 | Hund's Rule | 112 |
| 4.4.4 | Electron Configuration of Atoms and Ions | 112 |
| 4.5 | Electron Configurations and the Periodic Table | 115 |
| 4.5.1 | Blocks of the Periodic Table | 115 |
| 4.5.2 | Information from the electron configuration | 117 |
| | Multiple Choice Questions | 118 |
| | | |
| 5 | THE PERIODIC TABLE | 121 |
| 5.1 | Introduction | 121 |

| | | |
|-------|---|-----|
| 5.2 | Classification of Elements in the Periodic Table | 121 |
| 5.3 | Trends in Periodic Atomic Properties | 122 |
| 5.3.1 | Atomic Radius | 123 |
| 5.3.2 | Ionic Radius | 124 |
| 5.3.3 | First Ionisation Energy | 124 |
| 5.3.4 | Electron Affinity | 127 |
| 5.3.5 | Electronegativity | 127 |
| 5.3.6 | Electrical conductivity | 128 |
| 5.3.7 | Structure and chemical bonding | 128 |
| 5.3.8 | Melting and boiling point | 128 |
| 5.4 | Periodicity of Physical Properties of Period 2 and 3 Elements | 129 |
| 5.4.1 | Atomic Radius and Ionic Radius | 129 |
| 5.4.2 | Melting Point | 130 |
| 5.4.3 | Ionisation Energy | 131 |
| 5.4.4 | Electronegativity | 132 |
| 5.4.5 | Electrical Conductivity | 132 |
| 5.5 | Periodicity of Chemical Properties of Period 2 and 3 Elements | 133 |
| 5.5.1 | Reaction with Oxygen | 134 |
| 5.5.2 | Reaction with Water | 135 |
| 5.6 | Group 1 and 2 Elements | 135 |
| 5.6.1 | Physical Properties of Group 1 and 2 Elements | 136 |
| 5.6.2 | The trends of physical properties in Group 1 elements | 136 |
| 5.6.3 | The trends of physical properties in Group 2 elements | 137 |
| 5.6.4 | Chemical Properties of Group 1 and 2 Elements | 138 |
| 5.6.5 | Trend in Solubility of Group 1 and 2 Compounds | 142 |
| 5.6.6 | Trend in Thermo Decomposition of s-Block Compounds | 144 |
| 5.7 | Group 14 Elements | 145 |
| 5.7.1 | Variation in Physical Properties | 145 |
| 5.8 | Group 17 Elements | 151 |
| 5.8.1 | Variation in the Physical Properties of Group 17 Elements | 151 |
| 5.8.2 | General Chemical Properties of Group 17 Elements | 153 |
| 5.9 | An Introduction to the Chemistry of <i>d</i> -Block Elements | 156 |

| | | |
|---------------------------|--|------------|
| 5.9.1 | Electron Configuration | 156 |
| 5.9.2 | Exception for Cu and Cr | 157 |
| 5.9.3 | Physical Properties | 158 |
| 5.9.4 | Characteristic of Transition Elements | 160 |
| Multiple Choice Questions | | 164 |
| 6 | MOLECULES AND MOLECULAR STRUCTURE | 167 |
| 6.1 | Introduction | 167 |
| 6.2 | Ionic Bonding | 169 |
| 6.2.1 | Bonding in Ionic Compound and Giant Ionic Lattices | 167 |
| 6.2.2 | Strength of Ionic Bond | 169 |
| 6.3 | Covalent Bond and Coordinate Bond | 169 |
| 6.3.1 | Dot Cross Diagram (Lewis Structure) of the Covalent Bond | 170 |
| 6.3.2 | Multiple Covalent Bonds | 171 |
| 6.3.3 | Coordinate Bonds | 171 |
| 6.3.4 | Resonance Structures | 172 |
| 6.3.5 | Formal Charge and Lewis Structures | 173 |
| 6.3.6 | Giant Atomic Structures | 174 |
| 6.3.7 | Ionic to Covalent – A Continuum | 174 |
| 6.3.8 | Bond Polarity | 175 |
| 6.4 | Metallic Bonding | 177 |
| 6.4.1 | Electron Sea Model | 177 |
| 6.4.2 | Band Theory- Conductor, Insulator and Semiconductor | 178 |
| 6.5 | Molecular Shapes | 179 |
| 6.5.1 | The Valence Shell Electron Pair Repulsion (VSEPR) Theory | 180 |
| 6.5.2 | Shapes of Common Molecules | 181 |
| 6.5.3 | Effect of Lone Pair of Electrons and Electronegativity | 183 |
| 6.5.4 | Polar Molecules | 185 |
| 6.5.5 | Hybridisations of <i>s</i> and <i>p</i> Orbitals | 187 |
| 6.6 | Intermolecular Forces and Hydrogen Bonding | 192 |
| 6.6.1 | Van der Waals Forces | 192 |
| 6.6.2 | Hydrogen Bond | 193 |
| 6.7 | Bonding and Physical Properties | 195 |
| 6.7.1 | Effect of Bonding on Melting and Boiling Point | 195 |

| | | |
|----------|--|------------|
| 6.7.2 | Effect of Bonding on Solubility | 197 |
| | Multiple Choice Questions | 200 |
| 7 | ORGANIC CHEMISTRY I | 205 |
| 7.1 | Introduction | 205 |
| 7.2 | Hazard and Risk in Organic Chemistry | 205 |
| 7.2.1 | Managing Hazard and Calculating Risk | 206 |
| 7.2.2 | Reducing Risks | 207 |
| 7.2.3 | Pesticides and Comparative Risks | 207 |
| 7.3 | The Properties of Carbon Atom | 208 |
| 7.3.1 | Hybridisation of Carbon Atom | 209 |
| 7.3.2 | The Unique Properties of the Carbon Atom | 209 |
| 7.4 | Functional Groups and Homologous Series | 211 |
| 7.4.1 | Classification of Organic Compounds | 211 |
| 7.4.2 | Functional Groups | 212 |
| 7.5 | Representing Organic Compounds | 214 |
| 7.6 | Nomenclature | 216 |
| 7.7 | Isomerism | 218 |
| 7.7.1 | Constitutional Isomers | 218 |
| 7.7.2 | Stereoisomers | 219 |
| 7.8 | Organic Reactions and Reagents | 222 |
| 7.8.1 | Heterolytic Breakage | 222 |
| 7.8.2 | Homolytic Breakage | 223 |
| 7.8.3 | Organic Reagents | 223 |
| 7.8.4 | Organic Reactions | 224 |
| 7.8.5 | Organic Reaction Mechanisms | 225 |
| 7.9 | Alkanes (Paraffin) | 226 |
| 7.9.1 | The Origin of Alkanes | 226 |
| 7.9.2 | Sources of Alkanes | 226 |
| 7.9.3 | Crude Oil and Cracking | 229 |
| 7.9.4 | Nomenclature of Alkanes | 231 |
| 7.9.5 | Physical Properties of Alkanes | 233 |
| 7.9.6 | Isomerism | 235 |
| 7.9.7 | Cycloalkanes | 235 |
| 7.9.8 | Classification of Carbon Atoms | 236 |

| | | |
|--------|------------------------------------|-----|
| 7.9.9 | Chemical Properties of Alkanes | 236 |
| 7.10 | Alkenes (Olefins) | 241 |
| 7.10.1 | Stability of Alkenes | 245 |
| 7.10.2 | Reactions of Alkenes | 246 |
| 7.11 | Aromatic Compounds (Arenes) | 254 |
| 7.11.1 | Structure of Benzene Ring | 254 |
| 7.11.2 | Nomenclature of Aromatic Compounds | 256 |
| 7.11.3 | Reactions of Benzene | 260 |
| | Multiple Choice Questions | 271 |
| | Answers | 275 |
| | Glossary | 379 |
| | Index | 289 |

List of Figures

| | | |
|-------------|---|-----|
| Figure 1.1 | Classification of matter | 2 |
| Figure 1.2 | Indications of precision and accuracy | 11 |
| Figure 1.3 | Effect of electric field on a beam of protons, neutrons and electrons | 14 |
| Figure 1.4 | Effect of magnetic field on a beam of protons, neutrons and electrons | 15 |
| Figure 1.5 | The atomic symbol of an aluminium atom | 15 |
| Figure 1.6 | Mass spectrometer showing five basic parts | 18 |
| Figure 1.7 | Mass spectrometer – how it works | 18 |
| Figure 1.8 | Mass spectrum of sodium | 20 |
| Figure 1.9 | Mass spectrum of chlorine | 20 |
| Figure 1.10 | Mass spectrum of ethanol | 21 |
| Figure 2.1 | The formation of sodium chloride | 43 |
| Figure 2.2 | The formation of hydrogen molecule | 43 |
| Figure 2.3 | The formation of water molecule | 44 |
| Figure 2.4 | Test tubes showing the heights of precipitate | 49 |
| Figure 3.1 | Coffee-cup calorimeter | 75 |
| Figure 3.2 | “Bomb” calorimeter | 76 |
| Figure 3.3 | Enthalpy level diagram | 86 |
| Figure 3.4 | Enthalpy diagram for the formation of NaCl(s) | 89 |
| Figure 3.5 | Change in entropy | 91 |
| Figure 3.6 | The entropy changes with the changes of states | 93 |
| Figure 3.7 | Sign of free energy and spontaneity | 95 |
| Figure 4.1 | Rutherford’s model of helium atom | 101 |
| Figure 4.2 | Wavelengths | 102 |
| Figure 4.3 | The electromagnetic spectrum | 102 |
| Figure 4.4 | Continuous spectrum | 103 |
| Figure 4.5 | The line spectra of noble gases | 104 |
| Figure 4.6 | The line spectrum of hydrogen | 104 |
| Figure 4.7 | Electron transitions for hydrogen | 105 |
| Figure 4.8 | Bohr model of hydrogen atom | 105 |
| Figure 4.9 | The <i>s</i> orbitals | 110 |
| Figure 4.10 | The <i>p</i> orbitals | 110 |

| | | |
|-------------|--|-----|
| Figure 4.11 | The <i>d</i> orbitals | 110 |
| Figure 4.12 | Filling up of electrons according to the Aufbau principle | 111 |
| Figure 4.13 | Blocks in the periodic table | 115 |
| Figure 5.1 | Groups with common names | 121 |
| Figure 5.2 | The positions of metals, non-metals and metalloids in the Periodic Table | 122 |
| Figure 5.3 | The 1 st ionisation energy of the Period 2 and Period 3 elements | 125 |
| Figure 5.4 | First ionisation energies of Group 2 elements | 126 |
| Figure 5.5 | The successive ionisation energies for Na | 127 |
| Figure 5.6 | Relative atomic size of elements in Period 2 and 3 | 130 |
| Figure 5.7 | Periodicity of relative electrical conductivity for Periods 1 to 3 | 133 |
| Figure 5.8 | Flame colour of Group 1 and Group 2 elements | 138 |
| Figure 5.9 | Enthalpy change of solution of NaCl | 143 |
| Figure 5.10 | Decomposition of carbonate ion | 145 |
| Figure 5.11 | Relative stability of +2 and +4 oxidation states | 147 |
| Figure 5.12 | Complex ion $[\text{SnCl}_6]^{2-}$ | 148 |
| Figure 5.13 | Structure of diamond | 149 |
| Figure 5.14 | Structure of graphite | 149 |
| Figure 5.15 | Graphite in pencil | 150 |
| Figure 5.16 | Structure of amorphous carbon | 150 |
| Figure 5.17 | Buckminsterfullerene | 151 |
| Figure 5.18 | Halogens dissolve in cyclohexane | 153 |
| Figure 5.19 | Melting and boiling points of first transition series elements | 158 |
| Figure 5.20 | Formation of hexacyanoferrate(II) ion | 161 |
| Figure 5.21 | Splitting of <i>d</i> orbitals | 161 |
| Figure 5.22 | The colour of the $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ ion | 162 |
| Figure 5.23 | Splitting of <i>d</i> orbitals in Cu^+ and Ti^{4+} complexes | 162 |
| Figure 5.24 | Energy profile of a catalysed and an uncatalysed reaction | 162 |
| Figure 6.1 | Ionic lattice of sodium chloride | 167 |
| Figure 6.2 | The formation of Na^+ and Cl^- | 168 |
| Figure 6.3 | Formation of covalent bond between two F atoms | 170 |
| Figure 6.4 | Lewis structure of some main group elements | 170 |
| Figure 6.5 | Lewis structure of CH_4 | 170 |
| Figure 6.6 | Resonance structures of O_3 | 172 |
| Figure 6.7 | Resonance structures of C_6H_6 | 173 |

| | | |
|-------------|---|-----|
| Figure 6.8 | Pauling scale of electronegativity | 175 |
| Figure 6.9 | Bond polarity between H and Cl | 176 |
| Figure 6.10 | Electron sea model | 177 |
| Figure 6.11 | Energy bands in overlapping atomic orbitals | 178 |
| Figure 6.12 | Band theories in metal, insulator and semiconductor | 179 |
| Figure 6.13 | Polarity of CCl_4 and CHCl_3 molecules | 186 |
| Figure 6.14 | sp^3 hybridisation of carbon in CH_4 | 188 |
| Figure 6.15 | Tetrahedral structure of four hybrid orbitals of sp^3 | 189 |
| Figure 6.16 | Trigonal-pyramidal structure of NH_3 from four hybrid orbitals of sp^3 | 189 |
| Figure 6.17 | Bent structure of H_2O from four hybrid orbitals of sp^3 | 189 |
| Figure 6.18 | sp^2 hybridisation of carbon atom in $\text{H}_2\text{C}=\text{CH}_2$ | 190 |
| Figure 6.19 | σ and π bonds in ethene | 190 |
| Figure 6.20 | sp hybridisation of carbon atom in $\text{HC}\equiv\text{CH}$ | 191 |
| Figure 6.21 | σ and π bonds in $\text{HC}\equiv\text{CH}$ | 191 |
| Figure 6.22 | Permanent dipole-Permanent dipole interaction | 192 |
| Figure 6.23 | Instantaneous dipole-Induced dipole interaction | 192 |
| Figure 6.24 | London forces between Cl_2 molecules | 193 |
| Figure 6.25 | Boiling points of Group 14 hydrides | 193 |
| Figure 6.26 | Boiling points of Group 15, 16 and 17 hydrides | 194 |
| Figure 6.27 | Boiling points of hydrogen halides | 197 |
| Figure 6.28 | Ion dipole bonds between H_2O molecules and ions | 198 |
| Figure 6.29 | Separate layers of hexane and water liquids | 199 |
| Figure 6.30 | Miscibility of hexane and octane | 199 |
| Figure 7.1 | The valence electrons of a carbon atom | 208 |
| Figure 7.2 | The sp^3 hybridisation of s and p orbitals in carbon | 209 |
| Figure 7.3 | The sp^2 hybridisation of carbon atoms | 210 |
| Figure 7.4 | The sp hybridisation of carbon atom | 210 |
| Figure 7.5 | Molecule of (a) cholesterol, (b) linoleic Acid | 211 |
| Figure 7.6 | <i>cis-trans</i> isomerism in saturated ring compound | 220 |
| Figure 7.7 | Non-superimposable mirror image of enantiomer | 220 |
| Figure 7.8 | An achiral molecule with a plane of symmetry | 221 |
| Figure 7.9 | The formation of carbocation and carbanion | 223 |
| Figure 7.10 | The origin of hydrocarbon | 228 |
| Figure 7.11 | Primary distillation of petroleum | 229 |

| | |
|---|-----|
| Figure 7.12 Boiling points of <i>n</i> -alkanes and isoalkanes | 234 |
| Figure 7.13 The melting points of even and odd number alkanes | 235 |
| Figure 7.14 sp^2 hybridisation of ethene | 241 |
| Figure 7.15 <i>Entgegen</i> and <i>zusammen</i> molecules | 243 |
| Figure 7.16 Mechanism of electrophilic addition reaction | 247 |
| Figure 7.17 The mechanisms of syn addition | 247 |
| Figure 7.18 The addition reaction of hydrogen bromide with ethene | 250 |
| Figure 7.19 The electrophile substitution of benzene | 260 |
| Figure 7.20 Mechanism for Friedel-Crafts acylation | 266 |

List of Tables

| | | |
|------------|---|-----|
| Table 1.1 | SI Base Units | 3 |
| Table 1.2 | Common Decimal Prefixes Used with SI Units | 4 |
| Table 1.3 | Common SI – English Equivalent Quantities | 4 |
| Table 1.4 | Relative atomic mass and relative charge of subatomic particles | 14 |
| Table 2.1 | Units of concentration of solutions | 35 |
| Table 2.2 | Some metals that form more than one monatomic ion | 45 |
| Table 2.3 | Some common polyatomic ions | 45 |
| Table 2.4 | Volumes of KI and $\text{Pb}(\text{NO}_3)_2$ to be mixed | 50 |
| Table 2.5 | Quantitative information from the equation | 51 |
| Table 2.6 | Oxidation number of some common elements | 59 |
| Table 3.1 | Types of reaction | 73 |
| Table 3.2 | Molar enthalpies of neutralisation | 82 |
| Table 3.3 | The enthalpies of atomisation of elements at 25°C and 1.0 atm | 83 |
| Table 4.1 | Wavelengths of light in the hydrogen spectrum | 106 |
| Table 4.2 | Quantum numbers of an atomic orbital | 108 |
| Table 4.3 | Number of orbitals and electrons in a principal quantum number | 111 |
| Table 4.4 | Filling of electrons in orbitals | 112 |
| Table 4.5 | Electron configurations of elements at ground state | 113 |
| Table 4.6 | Valence shell electrons of <i>s</i> and <i>p</i> -blocks elements | 116 |
| Table 4.7 | Valence shell electrons of <i>d</i> -block elements | 116 |
| Table 4.8 | Valence shell electrons of Lanthanides | 117 |
| Table 5.1 | Number of energy levels in F, Ne and Na | 122 |
| Table 5.2 | Atomic number and nuclear charge of Be, Ne and Na | 123 |
| Table 5.3 | Number of shielding electrons in some elements | 123 |
| Table 5.4 | The effective nuclear charge of Be, Ne and Na | 123 |
| Table 5.5 | The first five successive ionisation energies of boron | 127 |
| Table 5.6 | The melting point and boiling point of Period 2 and Period 3 elements | 129 |
| Table 5.7 | Physical properties of Period 2 and Period 3 elements | 129 |
| Table 5.8 | Atomic structure of Period 3 elements | 130 |
| Table 5.9 | Melting point of Period 2 and Period 3 elements | 130 |
| Table 5.10 | Ionisation energy of Period 2 elements | 131 |
| Table 5.11 | Electronegativity of Period 2 and Period 3 elements | 132 |

| | | |
|------------|---|-----|
| Table 5.12 | Properties of Period 2 and 3 elements | 134 |
| Table 5.13 | Physical properties of Group 1 elements | 136 |
| Table 5.14 | 1 st and 2 nd ionisation energy of Group 1 elements | 137 |
| Table 5.15 | Physical properties of Group 2 elements | 138 |
| Table 5.16 | The first three ionisation energy of Group 2 elements | 138 |
| Table 5.17 | Flame test of Group 1 and Group 2 elements | 138 |
| Table 5.18 | Reactions of Group 2 elements with water | 140 |
| Table 5.19 | Solubility of Group 2 sulphates | 143 |
| Table 5.20 | Solubility of hydroxides of Group 2 elements | 144 |
| Table 5.21 | Decomposition temperature of Group 2 carbonates | 145 |
| Table 5.22 | Atomic structure of Group 14 elements | 146 |
| Table 5.23 | Atomic size and ionisation energy of Group 14 elements | 146 |
| Table 5.24 | Melting point of Group 14 elements | 146 |
| Table 5.25 | Bond energies of Group 14 elements | 148 |
| Table 5.26 | Atomic properties of Group 17 elements | 151 |
| Table 5.27 | Physical properties of Group 17 elements | 152 |
| Table 5.28 | Conditions of reactions between halogens and hydrogen | 154 |
| Table 5.29 | Bond energy of hydrogen halides | 155 |
| Table 5.30 | Electron configuration of first transition series elements | 157 |
| Table 5.31 | The density of first transition series elements | 158 |
| Table 5.32 | Ionisation energy of first transition series elements | 159 |
| Table 5.33 | Common oxidation states of first transition series elements | 160 |
| Table 5.34 | Catalysts in some commercial processes | 163 |
| Table 6.1 | The properties of sodium, chlorine and sodium chloride | 168 |
| Table 6.2 | Lattice energies for ionic compounds | 169 |
| Table 6.3 | Bond characteristics in correspond to the electronegativity difference | 175 |
| Table 6.4 | Average bond dipole moments in bonds | 177 |
| Table 6.5 | Melting points and boiling points of metals | 178 |
| Table 6.6 | Structures of common molecules | 178 |
| Table 6.7 | Boiling points of noble gases | 193 |
| Table 6.8 | The melting and boiling points of the 3 isomers of pentane | 196 |
| Table 6.9 | Boiling points of propan-1-ol, propane and butane | 196 |
| Table 6.10 | The solubility of common anions | 198 |
| Table 7.1 | Some of the international Hazchem symbols | 206 |
| Table 7.2 | Carbon-carbon single, double and triple bonds | 209 |

| | |
|---|-----|
| Table 7.3 Average bond enthalpy | 210 |
| Table 7.4 The functional groups in organic compounds | 213 |
| Table 7.5 The displayed and skeletal formula of some organic compounds | 215 |
| Table 7.6 The prefix for number of carbon atoms chain | 216 |
| Table 7.7 The suffix of homologous series | 217 |
| Table 7.8 Melting and boiling points of <i>cis-trans</i> isomers of but-2-ene | 220 |
| Table 7.9 Fractions of hydrocarbons from crude oil | 227 |
| Table 7.10 Density of some alkanes | 234 |
| Table 7.11 Alkenes with more than one double bond | 242 |
| Table 7.12 The comparisons between benzene with cyclohexene | 255 |
| Table 7.13 Common names for some monosubstituted benzene compounds | 256 |

Preface

This book, Chemistry I, is specially tailored for Pre-University students in Universiti Malaysia Sarawak who intend to pursue their studies in either biological or physical science courses. It covers all the topics of the course PRK1016, Chemistry I which is offered in Semester 1. This book provides a useful transition from school to university level as well as a suitable reference for STPM, A-level or any other pre-university and first year university chemistry courses.

The applications of chemistry have changed due to the numerous modern challenges such as the creation of a greener environment, reduction of global warming, determination of genetic makeup to treat diseases and others. The basic concepts of chemistry still form the essence of the course. Therefore, the book starts with the basic scientific methods of handling data with special emphasis on all units of measurements to be included in the steps of calculations. Then there is the conservation of mass and mole concept applied to the amount of substances involved in a chemical reaction. Thermochemistry relates heat and chemical changes. The atomic properties, the periodic trends of elements and types of bonding determine the molecular structures which in turn result in behaviour of substances. We also emphasised on mechanistic studies of most organic chemical reactions as understanding the mechanism of reactions would make the subject more interesting and easier to explore.

As conceptual learning and problem-solving are fundamental approaches to the study of chemistry, there are examples of problem-solving after each chemistry concept in the book. We also provide exercises as the tools for students to become critical thinkers and to learn to apply principles and rules. The answers for the exercises and multiple choice questions are provided at the end of each topic.

Lastly, as all the chemistry concepts have been presented as simple and clear as possible, we hope that this book will help students to gain sufficient chemistry knowledge to meet the requirement of any science courses at university level.

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UNIMAS

1 CHEMISTRY AND CHEMICAL NOMENCLATURE

1.1 Introduction

People, young or old, would always like to ask the question: "What is it made of?" This could be just natural curiosity, but it has led men to investigate the nature of the world around them. It has inspired great discoveries and led to advances in our knowledge.

1.2 Matter, Elements and Compounds

Chemistry deals with the properties and transformation of matter and the energy associated with those changes. One of the most important tasks of chemists is to study the nature of matter. Matter is anything that occupies **space** (volume) and has **mass** such as air, water, planets, and students. Matter occurs commonly in three physical states: solid, liquid or gas. It exists either as pure matter or impure matter. The pure matter can be an **element** or a **compound**, and impure matter is a **mixture** (Figure 1.1).

A complex substance can be broken down to simpler substance. A pure substance which cannot be chemically broken down into simpler substances is known as **element**. An element consists of only one type of particles and the particles can be either atoms or molecules.

Examples: Atoms: Na, K, Mg, etc

Molecules: O₂, H₂, Cl₂, etc

A **compound** is usually made up of two or more elements which are chemically bonded together so that the elements that make up the compound lose their identities and take on a new set of properties. A compound is made up of either molecules (molecular compounds) or ions (ionic compounds).

Examples: Molecular compound: H₂O, CO₂, NH₃, etc

Ionic compound: NaOH, NH₄OH, NaCl, MgSO₄ etc

A **mixture** is an impure matter consisting of two or more elements or compounds that are mixed without combining chemically. Each part of the matter in a mixture has its own identity (property). Each matter can be separated using physical or mechanical means.

There are two types of mixtures: heterogeneous mixtures and homogeneous mixtures. Heterogeneous mixtures are substances composed of two or more components that are not uniformly distributed throughout the system. They are immiscible, may be of different phase, and can be separated by mechanical means. Examples are sand and water (liquid and solid), oil and water (liquid and liquid), rock (solid and solid). A heterogeneous mixture is called a suspension or colloid.

Homogeneous mixtures are substances composed of two or more components that are uniformly distributed throughout the system. They are miscible, of a single phase, and cannot be separated by mechanical means. A homogeneous mixture is called a solution. Examples are vinegar (water and acetic acid are mixed evenly throughout), soft drinks, and glass.

An **atom** is the smallest neutral particle of an element that can take part in a chemical reaction. A **molecule** is a neutral particle made up of either atoms of the same element or atoms of different elements. For example, O_2 are molecules made up of atoms of same element; while CO_2 are molecules made up of atoms of different elements. An **ion** is a charged particle of either one atom, Na^+ ; or a group of atoms of different elements, SO_4^{2-} .

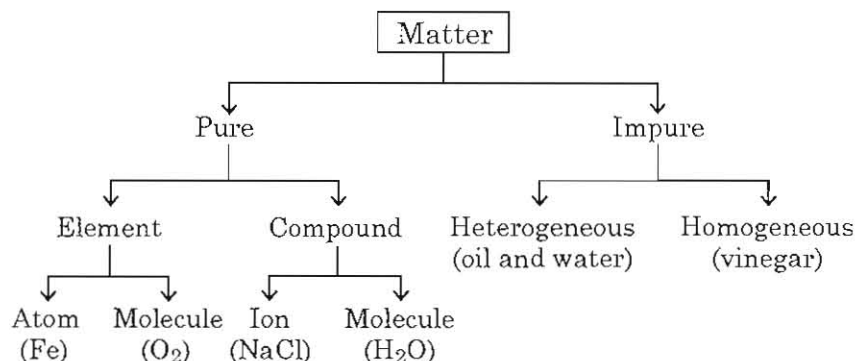
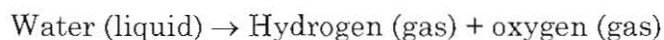


Figure 1.1 Classification of matter

Chemists observe two types of properties, physical and chemical, which are closely related to two types of change that matter undergoes. Physical properties are those that a substance shows by itself, without changing into or interacting with another substance. Physical properties include colour, melting point, density, electrical conductivity, and smell. A physical change occurs when a substance alters its physical form, not its composition.



Chemical properties are those that a substance shows as it changes into or interacts with another substance (or substances). Some examples of chemical properties are reactivity with acids, flammability, and corrosiveness. A chemical change (chemical reaction) occurs when a substance (or substances) is converted into a different substance (or substances).



Exercise 1.1

- Decide whether each of the following processes is a physical change or a chemical change, and explain briefly.
 - Dissolving sugar in water.
 - Dissolving sodium chloride in water.
 - Mixing acid and base.
 - An iron nail forming rust slowly in air.
 - Breaking a beaker.

1.2.1 Symbols and Formulae

The **symbols** of a chemical element are abbreviations that are used to denote a chemical element. Typically, they are one or two-letters long with the first letter capitalised. The elements with a single letter symbol are generally the common ones such as oxygen, or carbon, or they might be the only elements that start with that particular letter.

Most of the elements have double letter symbols. That second letter is usually the first non-common letter between elements that have names starting with the same letter. For example, chromium and chlorine both start with "C" and so does the symbol. They both have "h" for the second letter but the third letter is different; it is "l" for chlorine and "r" for chromium. Thus, the symbol for chlorine is Cl and for chromium is Cr.

The symbols of an element also represent specific amount of that element. For example, the symbol O represents one oxygen atom or 1 mole (6.02×10^{23}) of oxygen atoms; the symbol Na represents one sodium atom or 1 mole of sodium atoms.

Chemical Formulae represent chemical compounds showing the combination of the symbols of the constituents' elements. For example, the formula H_2O represents water or 1 mole of water molecule; the formula NaCl represents sodium chloride or 1 mole of sodium chloride.

1.3 Measurement in Scientific Study

In 1960, a metric system was established and accepted by scientists throughout the world. The units of this system are called SI units. Table 1.1 shows the SI system which is based on a set of seven fundamental units, or base units, each of which is identified with a physical quantity.

All other units, called derived units, are a combination of these seven base units. For example, the derived unit for speed, meter per second (m s^{-1}), is the base unit for length (m) divided by the base unit for time (s).

Table 1.1 SI Base Units

| Physical Quantity (Dimension) | Unit Name | Unit Abbreviation |
|----------------------------------|-----------|----------------------|
| Mass | Kilogram | kg |
| Length | Meter | m |
| Time | Second | s |
| Temperature | Kelvin | K |
| Electric Current | Ampere | A |
| Amount of Substance | Mole | mol |
| Luminous intensity | Candela | cd |

For quantities that are much smaller or much larger than the base unit, we use prefixes and exponential (scientific) notation. Table 1.2 shows the most important

prefixes. Exponential (scientific) notation provides a much more practical way of writing very large or very small quantities. They are expressed as:

$$A \times 10^n \quad \text{where } 1 \leq A < 10 \text{ and } n \text{ is an integer.}$$

Table 1.2 Common Decimal Prefixes Used with SI Units

| Prefix | Symbol | Number | Word | Exponential Notation |
|--------|--------|-------------------|------------|----------------------|
| tera | T | 1,000,000,000,000 | trillion | 10^{12} |
| giga | G | 1,000,000,000 | billion | 10^9 |
| mega | M | 1,000,000 | million | 10^6 |
| kilo | k | 1,000 | thousand | 10^3 |
| hecto | h | 100 | hundred | 10^2 |
| deka | da | 10 | ten | 10^1 |
| - | - | 1 | one | 10^0 |
| deci | d | 0.1 | tenth | 10^{-1} |
| centi | c | 0.01 | hundredth | 10^{-2} |
| milli | m | 0.001 | thousandth | 10^{-3} |
| micro | μ | 0.000001 | millionth | 10^{-6} |
| nano | n | 0.000000001 | billionth | 10^{-9} |
| pico | p | 0.000000000001 | trillionth | 10^{-12} |

Table 1.3 shows some useful SI quantities for length, volume, and mass, along with their equivalents in the English system. In chemistry, the most important volume units are liter (L) and milliliter (mL).

$$1 \text{ L} = 1 \text{ dm}^3 = 10^{-3} \text{ m}^3$$

$$1 \text{ mL} = 1 \text{ cm}^3 = 10^{-3} \text{ dm}^3 = 10^{-3} \text{ L}$$

Table 1.3 Common SI – English Equivalent Quantities

| Quantity | SI | SI Equivalents | English Equivalent | English to SI Equivalents |
|----------|--|--|------------------------------------|--|
| Length | 1 kilometer (km) | 1000 (10^3) meters | 0.6214 mile (mi) | 1 mile = 1.609 km |
| | 1 meter (m) | 100 (10^2) centimeters | 1.094 yards (yd) | 1 yard = 0.9144 m |
| | | 10^3 millimeters (mm) | 39.37 inches (in) | 1 foot (ft) = 0.3048 m |
| | 1 centimeter (cm) | 0.01 (10^{-2}) meter | 0.3937 inch | 1 inch = 2.54 cm |
| Volume | 1 cubic meter (m^3) | 1,000,000 (10^6) cubic centimeters | 35.31 cubic feet (ft^3) | 1 cubic foot = 0.02832 m^3 |
| | 1 cubic decimeter (dm^3)* | 10^3 cubic centimeters | 0.2642 gallons (gal) | 1 gallon = 3.785 dm^3 |
| | | | 1.057 quarts (qt) | 1 quart = 0.9464 dm^3 |
| | 1 cubic centimeter (cm^3)** | 0.001 (10^{-3}) dm^3 | 0.03381 fluid ounce | 1 quart = 946.4 cm^3 1 fluid ounce = 29.57 cm^3 |
| Mass | 1 kilogram (kg) | 1000 grams | 2.205 pounds (lb) | 1 pound = 0.4536 kg |
| | 1 gram (g) | 1000 milligrams (mg) | 0.03527 ounce (oz) | 1 ounce = 28.35 g |

* $\text{dm}^3 = \text{L}$; ** $\text{cm}^3 = \text{mL}$